Optimizing Microservices with GraphQL vs REST: A Comparative Analysis

Introduction

Microservices architecture revolutionized software design by enabling the creation of scalable applications through independently deployable services. This approach promotes agility in development, allowing teams to work on different services simultaneously without dependencies. It enhances fault tolerance, as failures in one service are less likely to impact the entire system. Moreover, microservices support the use of diverse technologies and programming languages for different components, enabling teams to choose the best tools for specific tasks. Ensuring efficient communication between these services is crucial for maintaining system responsiveness, reliability, and seamless user experiences.

This project explores the implementation of a microservices architecture, emphasizing service design through both GraphQL and REST technologies. We perform a comparative analysis of their performance to evaluate their effectiveness in modern web application frameworks.

Feature	REST	GraphQL
Definition	REST (Representational State Transfer) is an architectural style with rules and constraints for creating web services using HTTP methods.	GraphQL is a query language and specification for building APIs, typically using a single endpoint (/graphql).
Request Methods	Uses HTTP methods like GET, POST, PUT, and DELETE for different actions.	Uses a single endpoint for all requests, regardless of the type of action.
Data Fetching	Fetches all records or data defined by the server's response.	Allows the client to specify precisely what data it needs, optimizing payload size.
Documentation	Requires additional effort to create comprehensive documentation for the API.	Offers a self-documenting schema, making API structure easier to understand and query.

Application Overview

The purpose of this application is to provide an easy-to-use interface for retrieving movie data from a database, either via a RESTful API or a GraphQL API. Users can query for movie information based on two key parameters:

1. **Number of Years (num_years):** Fetch movies from the past N years.
2. **Specific Year (year):** Fetch movies from a specific year.

The application supports two types of endpoints for accessing the movie data:

- **REST API:** Offers a simple way to retrieve movie data by year or number of years. Users can send a GET request to retrieve the movie list for the specified parameters.

- **GraphQL API:** Provides a more flexible query interface, allowing users to specify exactly what movie data they want. Users can query for movies based on the number of years or a specific year, and retrieve selected fields such as title, genre, director, actors, plot, and more.

The **key features of the application** include:

- Fetching movie data based on the number of years or a specific year.
- Ability to return movie details such as title, year, genre, director, actors, plot, awards, and poster image.
- Two APIs (REST and GraphQL) that offer different approaches to data retrieval, with REST offering simplicity and GraphQL offering flexibility in specifying data needs.

This application is ideal for accessing and managing movie data in a way that allows for efficient querying based on temporal criteria (such as year or range of years). It serves as a flexible solution for both simple and complex data access needs.

Design Considerations

The choice between REST and GraphQL depends on the specific needs of our project. REST is suitable for straightforward, cacheable communication protocols and is often preferred for public-facing APIs. GraphQL on the other hand, is ideal for complex applications with rapidly changing front-end requirements, offering greater flexibility and efficiency in data retrieval.

Following design choices were considered while implementing the application using both REST and GraphQL frameworks.

Architecture

REST:
Operates through multiple endpoints, with each endpoint exposing a specific resource. Clients interact with these endpoints using various HTTP methods (GET, POST, PUT, PATCH, DELETE) to perform different operations. The decentralized nature of endpoints can result in a more complex API structure, often requiring additional management for versioning

GraphQL:
Adopts a single-endpoint approach, typically /graphql, to handle all queries and mutations. Clients send GraphQL queries to this endpoint, specifying exactly what data they need. Simplifies the API structure and reduces the overhead associated with endpoint proliferation and version control.

Efficiency

REST:
Fixed data structures returned from each endpoint can lead to inefficiencies. *Over-fetching:* Receiving more data than necessary, *Under-fetching:* Requiring multiple requests to gather all required data. Such inefficiencies can impact applications with limited bandwidth or real-time data requirements.
GraphQL:
Enables clients to request only the specific data they need in a single query. Avoids the pitfalls of over-fetching and under-fetching, optimizing network usage particularly beneficial for mobile and low-bandwidth scenarios.

Schema design

REST:
Lacks a built-in schema or type system. Data structures are defined on the server, requiring clients to adapt to these predefined formats and relies heavily on manual documentation for API structure and usage

GraphQL:
Employs a strongly typed schema written in GraphQL Schema Definition Language (SDL). This schema acts as a contract between the client and server, ensuring data consistency and facilitating tooling and automation such as automatic code generation and API documentation

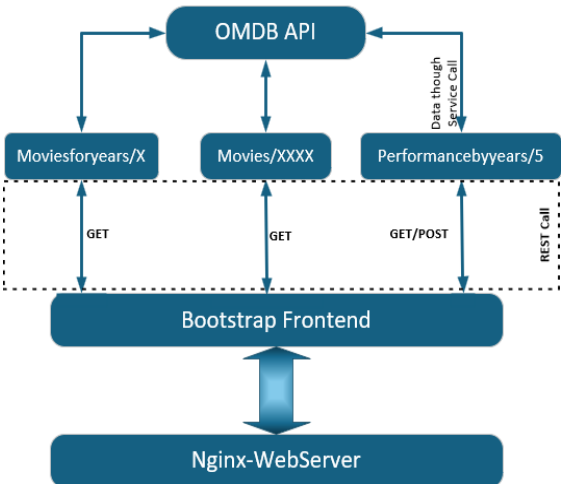
Error handling

REST:
Uses standard HTTP status codes to indicate errors. Each status code has a specific meaning, such as 200 for success, 400 for client errors, and 500 for server errors

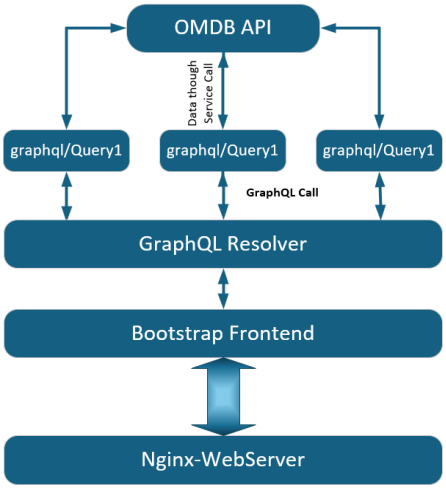
GraphQL:
Delivers errors in the response payload alongside the correct data. This approach provides a more nuanced error handling mechanism, where the "errors" entry in the response body details the specific errors encountered

System Architecture

Below Architecture diagrams depict the approach taken towards designing the service interaction between various system components both in the case of REST and GraphQL.

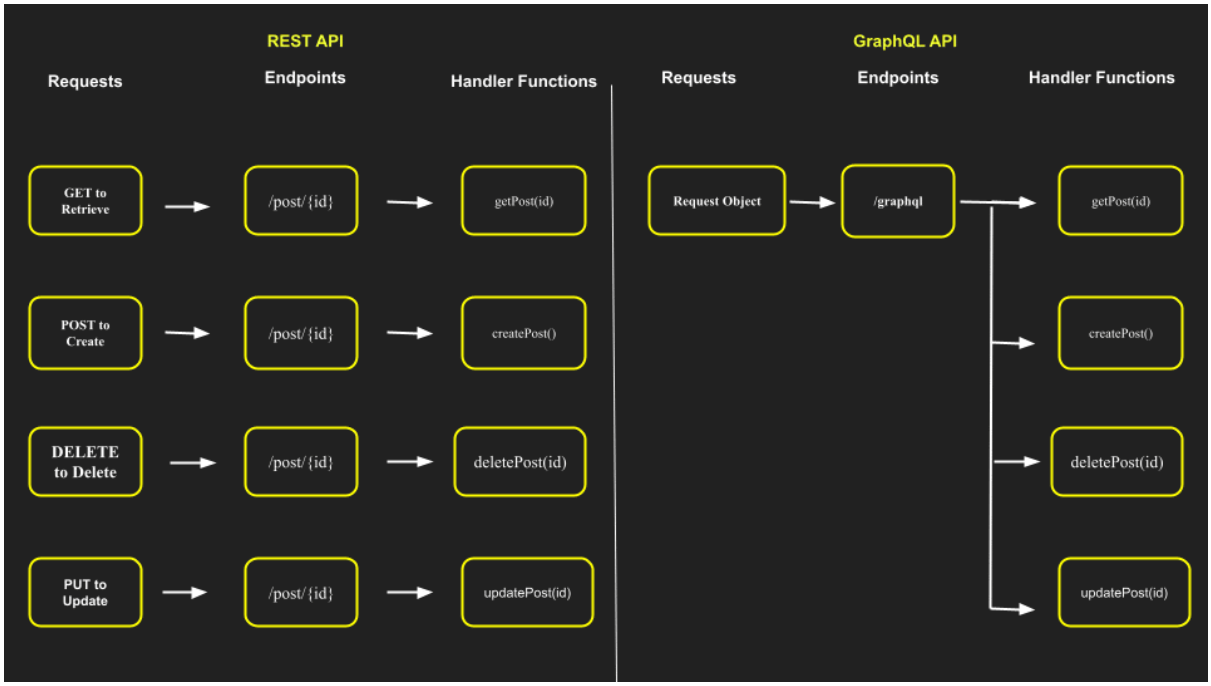


REST



GraphQL

The architecture of a web application using REST is characterized by multiple endpoints, fixed data structures and the potential for over-fetching or under-fetching. In contrast, GraphQL uses a single endpoint, allows for flexible and precise data retrieval and supports real-time updates and continuous schema evolution without versioning. These differences make GraphQL more suitable for complex applications with rapidly changing front-end requirements, while REST remains a good choice for simpler, more structured APIs.



Following are the key design approach differences when building a web application using REST vs GraphQL

1. **Endpoint Structure**: REST uses multiple endpoints, while GraphQL uses a single endpoint.

2. **Data Retrieval**: REST returns fixed data structures, while GraphQL allows clients to specify exact data needs.

3. **Schema and Type System**: REST does not enforce a schema, while GraphQL uses a strongly typed schema.

4. **Versioning**: REST requires versioning, while GraphQL does not.

5. **Network Requests**: REST can lead to multiple network requests, while GraphQL reduces network round trips.

6. **Error Handling**: REST uses HTTP status codes, while GraphQL includes errors in the response payload.

7. **Real-Time Updates**: REST does not support real-time updates out of the box, while GraphQL does through subscriptions.

8. **Flexibility and Customization**: GraphQL offers more flexibility in data retrieval compared to REST.

Experimentation & Performance testing

We undertook load testing of the application by simulating 100 concurrent users and a Spawn rate of 20, 40 and 60 secs. For this purpose, we used Locust. Locust is an open-source load testing tool designed to evaluate the performance and scalability of various systems, including websites, applications, and other networked services. Locust allows users to define test scenarios in plain Python code, making it easy to simulate real-user behavior. Users can create scripts that mimic the actions of real users, such as navigating through a website, logging in, and performing various tasks.

Following are the load testing results as recorded during experimentation with the application.

REST test statistics

100 users with spawn rate 20s and User acceleration of 5

Type	Name	# Requests	# Fails	Median (ms)	95%ile (ms)	99%ile (ms)	Average (ms)	Min (ms)	Max (ms)	Average size (bytes)	Current RPS	Current Failures/s
GET	/movies/2023	45	0	3900	5800	6100	4224.19	3341	6082	147539	3.2	0
GET	/moviesforyears/1	29	0	5100	8200	8400	5677.59	4597	8388	287313	2.4	0
	Aggregated	74	0	4600	7600	8400	4793.76	3341	8388	202315.3	5.6	0

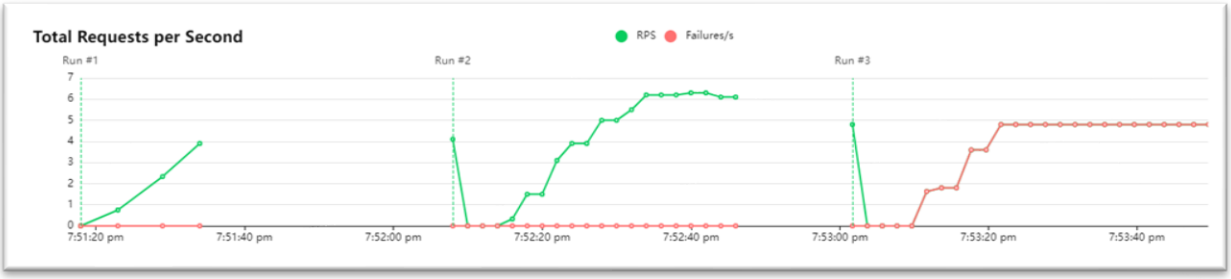
100 users with spawn rate 40s and User acceleration of 4

Type	Name	# Requests	# Fails	Median (ms)	95%ile (ms)	99%ile (ms)	Average (ms)	Min (ms)	Max (ms)	Average size (bytes)	Current RPS	Current Failures/s
GET	/movies/2023	97	0	5900	11000	11000	6766.32	3499	11327	147539	3.7	0
GET	/moviesforyears/1	81	0	8800	14000	15000	9147.6	4812	15197	287313	2.7	0
	Aggregated	178	0	7700	13000	14000	7849.93	3499	15197	211144.02	6.4	0

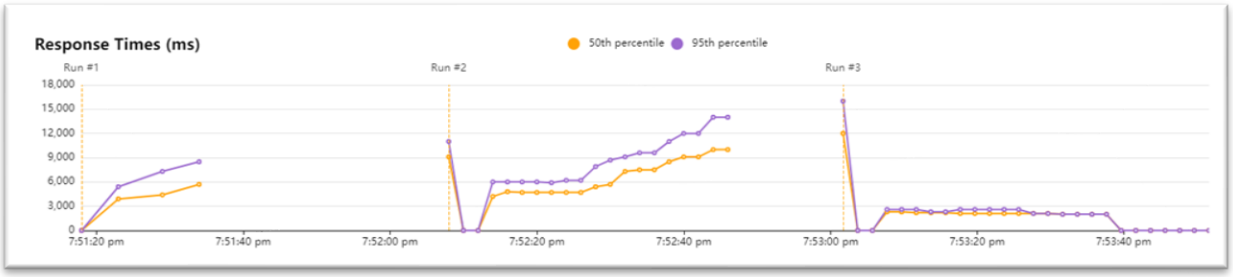
100 users with spawn rate 60s and User acceleration of 2

Type	Name	# Requests	# Fails	Median (ms)	95%ile (ms)	99%ile (ms)	Average (ms)	Min (ms)	Max (ms)	Average size (bytes)	Current RPS	Current Failures/s
GET	/movies/2023	43	43	2100	2600	2800	2174.84	2035	2774	25207.95	2.4	2.4
GET	/moviesforyears/1	38	38	2100	2600	2600	2132.92	2034	2617	16403.68	2.4	2.4
	Aggregated	81	81	2100	2600	2800	2155.17	2034	2774	21077.56	4.8	4.8

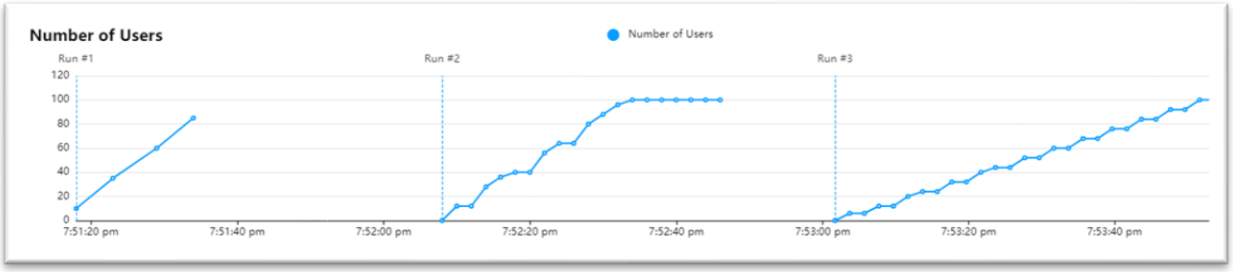
Total Request per Second



Response Time with variation in Users and Requests



Number of Users Variations for Requests



GraphQL test statistics

100 users with spawn rate 20s and User acceleration of 5

Name	# Requests	# Fails	Median (ms)	95%ile (ms)	99%ile (ms)	Average (ms)	Min (ms)	Max (ms)	Average size (bytes)	Current RPS	Current Failures/s
/graphql	172	0	2100	2100	2100	2076.17	2032	2137	1747	10.6	0
Aggregated	172	0	2100	2100	2100	2076.17	2032	2137	1747	10.6	0

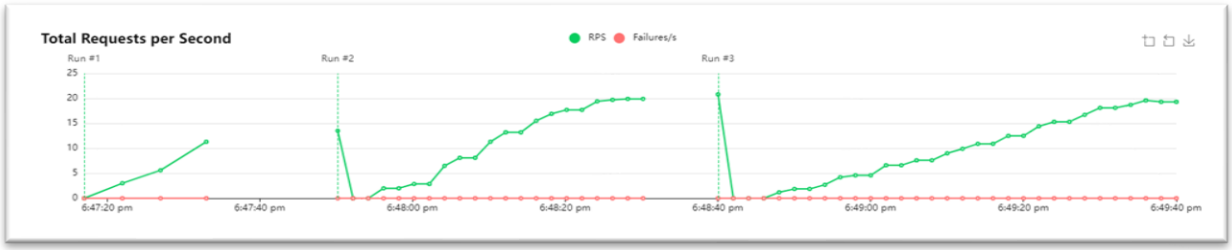
100 users with spawn rate 40s and User acceleration of 4

Name	# Requests	# Fails	Median (ms)	95%ile (ms)	99%ile (ms)	Average (ms)	Min (ms)	Max (ms)	Average size (bytes)	Current RPS	Current Failures/s
/graphql	528	0	2100	2100	2100	2070.03	2034	2162	1747	19.6	0
Aggregated	528	0	2100	2100	2100	2070.03	2034	2162	1747	19.6	0

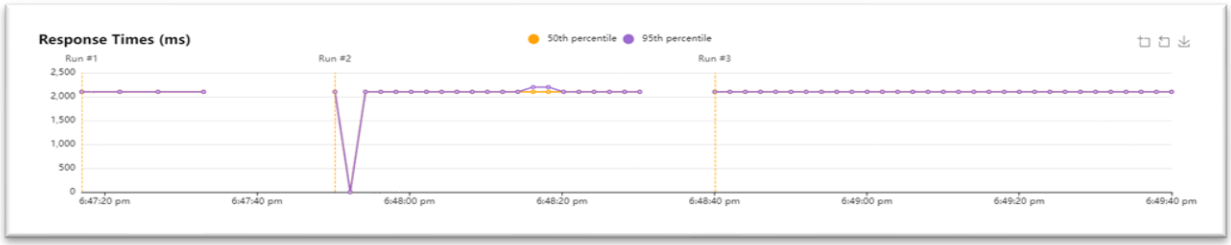
100 users with spawn rate 60s and User acceleration of 2

Name	# Requests	# Fails	Median (ms)	95%ile (ms)	99%ile (ms)	Average (ms)	Min (ms)	Max (ms)	Average size (bytes)	Current RPS	Current Failures/s
/graphql	671	0	2100	2100	2100	2064.97	2031	2148	1747	19.3	0
Aggregated	671	0	2100	2100	2100	2064.97	2031	2148	1747	19.3	0

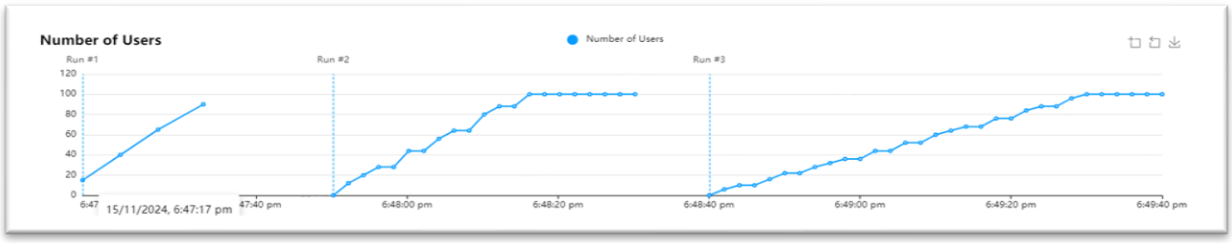
Total Request per Second



Response Time with variation in Users and Requests



Number of Users Variations for Requests



Conclusion & Analysis

In a test scenario involving 100 users with a spawn rate of 20, 40 and 60, GraphQL demonstrates better performance in terms of data fetching efficiency and reduced network requests.

GraphQL performs better in terms of data fetching efficiency. With GraphQL, clients can specify exactly the data they need, reducing over-fetching and under-fetching issues. This results in fewer network requests and less redundant data being transferred. For example, if each user needs to fetch a user profile along with their posts, GraphQL can handle this with a single query, whereas REST would require multiple requests.

GraphQL

- Fewer network requests
- Reduced data fetching time
- More efficient handling of complex data relationships
- Potential drawbacks in caching efficiency

REST

- Higher number of network requests
- Increased latency due to multiple round trips
- Better caching efficiency, though this may be less significant at high spawn rates
- Simpler error handling using HTTP status codes